Significant New Alternatives Policy Program
Refrigeration and Air-conditioning Sector

Risk Screen on Substitutes in Residential and Light Commercial Air-conditioning and Heat Pumps

Substitute: HFC-134a (Summit Plus)

This risk screen does not contain Clean Air Act (CAA) Confidential Business Information (CBI) and, therefore, may be disclosed to the public. Brackets [ ] represent redacted CBI content.

1. INTRODUCTION

Ozone-depleting substances (ODS) are being phased out of production in response to a series of diplomatic and legislative efforts that have taken place over the past two decades, including the Montreal Protocol and the Clean Air Act Amendments of 1990 (CAAA). The U.S. Environmental Protection Agency (EPA), as authorized by Section 612 of the CAAA, administers the Significant New Alternatives Policy (SNAP) Program, which identifies acceptable and unacceptable substitutes for ODS in specific end-uses based on assessment of their health and environmental impacts.

EPA's decision on the acceptability of a substitute is based on the findings of a screening assessment of potential human health and environmental risks posed by the substitute in specific applications. EPA has already screened a large number of substitutes in many end-uses and applications within all of the major ODS-using sectors including: refrigeration and air-conditioning; solvent cleaning; foam blowing; aerosols; fire suppression; adhesives, coatings and inks; and sterilization. The results of these risk screens are presented in a series of Background Documents that are available in EPA's docket.

The purpose of this risk screen is to supplement EPA's Background Document on the refrigeration and air-conditioning sector (EPA 1994) (hereinafter referred to as the Background Document). This risk screen evaluates the potential use of HFC-134a (also known as Summit Plus) as a substitute in retrofit of equipment in the residential and light commercial air-conditioning (AC) and heat pumps end-use. Table 1 presents the composition of the proposed substitute.

Table 1. Composition of HFC-134a and Potential Impurities

Constituent	Chemical Formula	CAS Number	Concentration (Weight Percent)
1,1,1,2-Tetrafluoroethane (HFC-134a)[a]	CF_3CH_2F	811-97-2	[ ]
Potential Impurities (Maximum Concentration)			
Other Refrigerants	NA	NA	<0.5%
Non-condensables	NA	NA	<1.5% (volume)
High Boiling Residue	NA	NA	<0.01% (volume)
Acid	NA	NA	<0.000001% (volume)
Water	NA	NA	<0.00001% (volume)

NA = Not available.
[a] [ ].

Section 2 summarizes the results of the risk screen for the proposed substitute listed in Table 1. The remainder of the risk screen is organized into the following sections:

- Section 3: Atmospheric Assessment
- Section 4: Volatile Organic Compound Assessment
- Section 5: Discussion of End-Use Scenarios

- Section 6: Potential Health Effects
- Section 7: Flammability Assessment
- Section 8: Asphyxiation Assessment
- Section 9: End-Use Exposure Assessment
- Section 10: Occupational Exposure Assessment
- Section 11: General Population Exposure Assessment
- Section 12: References

2. SUMMARY OF RESULTS

HFC-134a is recommended for SNAP approval for retrofit of equipment in the residential and light commercial AC and heat pumps end-use. EPA's risk screen indicates that the use of the proposed substitute will be less harmful to the atmosphere than the continued use of ODS and other commonly used refrigerants, as it is less harmful to the ozone layer, has lower climate impact, and a shorter atmospheric lifetime (ALT).

HFC-134a is excluded from the definition of volatile organic compounds (VOC) under CAA regulations (40 CFR 51.100(s)), so impacts on local air quality from the release of HFC-134a are not a concern. In addition, because HFC-134a is considered to be nonflammable, the proposed substitute is not expected to present a flammability concern. It is expected that the safety data sheet (SDS) for HFC-134a and good manufacturing practices will be adhered to during handling or use of HFC-134a, and that appropriate safety and personal protective equipment (PPE) (e.g., protective gloves, tightly sealed goggles, protective work clothing, and suitable respiratory protection in case of leakage or insufficient ventilation) consistent with Occupational Safety and Health Administration (OSHA) guidelines will be used during charging, servicing, and disposal of residential and light commercial AC and heat pumps retrofitted with HFC-134a. Because these systems are installed in locations with adequate space and/or ventilation in accordance with EPA recommendations and the equipment maintenance manuals for HFC-134a in each end-use, significant toxicity risk to consumers and personnel is also unlikely.

Additional safeguards are also provided by adherence to industry standards including American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standards 15,[1] 34,[2] and 62.1,[3] Air-conditioning, Heating, and Refrigeration Institute (AHRI) Standard 700,[4] and Underwriter's Laboratory (UL) Standard 484.[5]

3. ATMOSPHERIC ASSESSMENT

This section presents an assessment of the potential risks to the atmosphere posed by the use of HFC-134a in residential and light commercial AC and heat pumps. The ozone depletion potential (ODP), global warming potential (GWP), and ALT of the proposed substitute are presented in Table 2.

The proposed substitute is substantially less harmful to the ozone layer, has comparable or lower climate impact, and a comparable or shorter ALT when compared to refrigerants such as CFC-12 and HCFC-22.

[1] Safety Standard for Refrigeration Systems ASHRAE Standard 15 establishes safeguards for life, limb, health, and property and prescribes safety requirements.
[2] Designation and Safety Classification of Refrigerants ASHRAE Standard 34 establishes a uniform system for assigning reference numbers, safety classifications, and refrigerant concentration limits to refrigerants. Safety classifications based on toxicity and flammability data are included.
[3] Ventilation for Acceptable Indoor Air Quality ASHRAE Standard 62.1 establishes minimum ventilation rates and other measures intended to provide indoor air quality that is acceptable to human occupants and that minimizes adverse health effects.
[4] AHRI Standard 700: Standard for Specifications for Refrigerants establishes purity specifications and specifies the associated methods of testing for acceptability of refrigerants regardless of source (new, reclaimed, and/or repackaged) for use in new and existing refrigeration and air-conditioning products within the scope of AHRI.
[5] UL 484 Standard for Safety: Room Air Conditioners establishes safety requirements for room air conditioners that are designed to provide delivery of conditioned air to an enclosed space, room, or zone.

HFC-134a has lower climate impact than those predicted for other substitutes examined in the Background Document, as well as commonly utilized refrigerants in residential AC applications, including R-410A and R-407C. Thus, EPA believes that the use of HFC-134a would result in substantially less harm to the climate and ozone layer than the continued use of ODS and other commonly used refrigerants.

Table 2. Atmospheric Impacts of HFC-134a Compared to Other Refrigerants Used in Residential and Light Commercial AC and Heat Pumps

Refrigerant	Ozone Depleting Potential (ODP)[a]	Global Warming Potential (GWP)[b]	Atmospheric Lifetime in Years (ALT)[b]
HFC-134a	0	1,430	14
Other Refrigerants			
HCFC-22	0.13	1,810	12[a]
R-410A[c]	0	2,088	NA[d]
R-407C[e]	0	1,774	NA[f]

NA = Not applicable.
[a] World Meteorological Organization (WMO) 2010 Scientific Assessment Report (2011).
[b] Intergovernmental Panel on Climate Change (IPCC 4th Assessment Report (Forster et al. 2007).
[c] R-410A is a blend comprising HFC-32 (50%) and HFC-125 (50%).
[d] The ALT for HFC-32 is 4.9 years and the ALT for HFC-125 is 29 years (Forster et al. 2007).
[e] R-407C is a blend consisting of HFC-32 (23%), HFC-125 (25%), and HFC-134a (52%).
[f] The ALT for HFC-32 is 4.9 years, the ALT for HFC-125 is 29 years, and the ALT for HFC-134a is 14 years (Forster et al. 2007).

4. VOLATILE ORGANIC COMPOUND ASSESSMENT

HFC-134a is excluded from the definition of VOC under CAA regulations (40 CFR 51.100(s)). Therefore, VOC impacts from the release of HFC-134a are not a concern.

5. DISCUSSION OF END-USE SCENARIOS

HFC-134a is being evaluated for retrofit of residential and light commercial AC and heat pumps, which includes room AC systems (i.e., window AC, portable AC, packaged terminal air conditioners [PTAC] and heat pumps [PTHP]), non-ducted split systems (mini- and multi-split), ducted split systems (i.e., unitary AC), packaged rooftop units, and water-source and ground-source heat pumps. The typical and maximum charge sizes for these systems are shown in Table 3.

Table 3. Charge Sizes for HFC-134a Residential AC Applications[a]

Application	Typical Charge Size (kg)	Maximum Charge Size (kg)
Window AC, Portable AC	0.2	1
PTAC/PTHP	0.6	1
Ductless split	**0.5**	**5**
Water- and Ground-Source Heat Pumps	3.5	4
Ducted split	**3**	**10**
Packaged Rooftop Units	5	100

Bolded applications and charge sizes represent those modeled in this risk screen.
[a] The submitter did not provide specific information regarding the charge sizes for residential and light commercial AC and heat pumps. Thus, charge sizes are assumed to be consistent with EPA's Vintaging Model and UNEP (2015a, 2015b).

Ducted split AC systems consist of an air conditioner or heat pump installed outside a home that is attached to an air handler, which is installed inside the home (e.g., in a basement) and conditioned air travels through the home via a distribution of ductwork. Packaged rooftop units are installed on the roof of a home or building and produce conditioned air within the same system (i.e., compressor, evaporator, and condenser are housed within a single unit), which is distributed throughout the home or building via ductwork. Water- and ground-source heat pumps are installed outdoors and provide heating and cooling via either forced air (i.e., for forced air furnaces or central AC systems utilizing ductwork) or water (i.e., for radiators or underfloor heating).

Ductless split AC systems consist of an outdoor condensing unit that is connected via refrigerant piping to one or more evaporators installed within individual rooms. Room AC systems are typically installed in a window, through a wall, or as a console located in or adjacent to the space being conditioned.

Ductless split AC systems are classified as “high-probability systems” by ASHRAE Standard 15 (i.e., high probability that leakage of refrigerant will enter an occupied space), because if there is a leak from one evaporator unit in one room, the system has the potential to leak the entire refrigerant charge for that AC network into only that one room (ASHRAE 2016a). If a catastrophic leak in a ductless split AC system occurred, the refrigerant from the entire system could be released into one of the rooms where the evaporator is located (e.g., a bedroom). Similarly, if a catastrophic leak from a room AC unit occurred, the refrigerant from the unit would be released into the room where the unit is installed.

For ducted systems, water- and ground-source heat pumps, and packaged rooftop units, in the event of a catastrophic leak while the AC system is operating, the entire refrigerant charge of the unit would likely escape from the unit through the duct system and be dispersed throughout the connected rooms via the vents, and ventilation from the duct system would mitigate exposures to high concentrations of the refrigerant. It is unlikely that the refrigerant would be distributed through the duct system into a single room. Conversely, if a catastrophic leak occurs while a ducted split AC system or a water- and ground-source heat pump is not operating (e.g., due to a puncture of the refrigerant line), the refrigerant would be expected to release entirely into the room where the air handler is located. A catastrophic leak from a packaged rooftop unit while the system is not operating would be to the outdoors where the unit is installed.

To represent reasonable worst-case scenarios with the greater potential concern across all residential and light commercial AC and heat pump applications, this risk screen evaluates three scenarios in which a catastrophic leak of refrigerant occurs in a bedroom where a window AC or ductless split system is located and in a basement where the air handler for a ducted split AC system is located.

The analyses in this risk screen conservatively assume that the bedroom has an effective volume of 41 m^3 (1,450 ft^3) (i.e., excluding the space filled by furniture) and a height of 2.4 meters (8 feet). Based on minimum floor areas of urban single family homes, the basement is assumed to have an effective volume of 136 m^3 (4,800 ft^3) (i.e., excluding the space filled by furniture, air ducts) and a height of approximately 2.4 meters (i.e., a standard 8-foot ceiling) (U.S. DOE 2016).

For these reasonable worst-case scenarios, the full charge of the unit is assumed to be emitted over the course of one minute into a bedroom or basement under scenarios with 0.11 air changes per hour (ACH) and 0.67 ACH.[6] During the cooling season (May to September), ACH in spaces with a floor area of 900 square feet or less are reported to be between 0.11 ACH for tight construction and 0.67 ACH for loose construction (ACCA 2006). Therefore, this risk screen models both air exchange rates, 0.11 ACH and 0.67 ACH, in order to account for use of units in homes with different construction practices.

Since HFC-134a is denser than air (specific gravity of HFC-134a is 1.22 (air=1)) and will settle in higher concentrations closer to the ground, a vertical concentration gradient is also assumed. In order to simulate

[6] The EPA Exposure Factors Handbook (1997) states that the typical residential air exchange rate is 0.45 ACH, which factors in tests from homes that are greater than 45 years old as well as those that are less than 10 years old. However, older homes (i.e., built before 1994) are more likely to use window or wall AC units than newer homes. Based on data of AC use in U.S. homes by year of construction, 27 percent of homes using AC equipment use window or wall AC units, while the remaining use central AC equipment (EIA 2013). On average, 38 percent of homes built before 1990 use window or wall AC units in comparison to the average of 9 percent of homes built after 1990. Air exchange rates are expected to be greater in older homes that are typically built with loose construction practices (e.g., no or inadequate effort to seal structural panels, corners, cracks, joints, and penetrations; window and door assemblies are not rated). Additionally, if a home uses window or wall AC units, EPA does not expect that there is any significant mechanical ventilation present in the home.

the vertical concentration gradient of refrigerant following release, it is assumed that 95 percent of the leaked refrigerant mixes evenly into the lower meter (3.3 feet) for window AC, 1.8 meters (5.9 feet) for ductless split systems, or 0.4 meters (1.3 feet) for ducted split systems of the room and the rest of the refrigerant mixes evenly in the remaining volume (Kataoka 2000). These vertical concentration gradient heights are based on UL 484 assumptions that window AC and ductless split systems are installed at a height of 1 meter and 1.8 meters above the ground, respectively. For ducted systems, which are not covered by UL 484, this analysis assumes that refrigerant would leak from the air handler into the bottom 0.4 meters of the room. Table 4 details the modeling assumptions used in Sections 8 and 9.

Table 4. End-Use Scenario Model Assumptions

Parameter	Assumptions		
AC Unit	Window AC	Ductless split System	Ducted split System
Charge Size (kg)	1	5	10
Length of Release (minutes)	1	1	1
Room Type	Bedroom	Bedroom	Basement
Size (m^3)	41[a] (1,450 ft^3)	41[a] (1,450 ft^3)	136[b] (4,800 ft^3)
Ventilation Rate (ACH)	0.11[c]; 0.67[d]	0.11[c]; 0.67[d]	0.11[c]; 0.67[d]
Vertical Concentration Gradient (m)	1 (3.3 ft.)[e]	1.8 (5.9 ft.)[e]	0.4 (1.3 ft.)

[a] Background Document (EPA 1994).
[b] U.S. DOE (2016).
[c] Tight construction home (ACCA 2006).
[d] Loose construction home (ACCA 2006).
[e] UL (2012).

EPA recognizes that AC units may have different charge sizes than modeled in this risk screen and may be placed in rooms, homes, or buildings with differing volumes. When units are installed in smaller, enclosed spaces, there is a higher concern for risks associated with flammability, asphyxiation, and/or exposure. To address the variability in charge sizes and room volumes for installed AC units, this risk screen incorporates threshold analyses in addition to the reasonable worst-case scenario modeling for scenarios in which the results of the screening-level assessment warrant further risk evaluation.

HFC-134a is nonflammable and the acute toxicity exposure limit (ATEL) (see Section 6) is lower than the concentration necessary to reduce oxygen in air to the hypoxia no observed adverse effect level (NOAEL).[7] Therefore, a threshold analysis is performed in the end-use exposure assessment for this risk screen to determine the room size and charge size requirements at which an acute toxicity concern would exist for the use of HFC-134a in residential and light commercial AC and heat pumps.

6. POTENTIAL HEALTH EFFECTS

To assess potential health risks from exposure to the proposed substitute in residential and light commercial AC and heat pumps, EPA identified the relevant toxicity threshold values and compared them to modeled exposure concentrations for different scenarios. According to ASHRAE Standard 34, HFC-134a is listed under safety group A1 with an ATEL and RCL of 50,000 parts per million (ppm) (ASHRAE 2016b). ASHRAE 34 ATELs and RCLs[8] are intended to reduce the risks of acute toxicity, asphyxiation, and flammability hazards in normally occupied, enclosed spaces during refrigerant use and protect end-users from the potential dangers of a catastrophic leak from a refrigeration unit (ASHRAE 2016b). The ATEL for HFC-134a is intended to reduce the risk of cardiac sensitization, which is the most hazardous potential health effect from significant exposure to HFC-134a. As such, this risk screen

[7] Twelve percent oxygen in air is the NOAEL for hypoxia (ICF 1997).
[8] ASHRAE Standard 15 implements ASHRAE 34, requiring that "the concentration of refrigerant in an enclosed space following a complete discharge of a high-probability system shall not exceed the RCL" (ASHRAE 2016a).

references the ATEL and RCL in addition to the hypoxia NOAEL and occupational exposure limits, as additional, conservative limits to ensure that significant toxicity and asphyxiation risks do not occur.

Using the exposure scenarios described in Section 5, risks from potential one-time consumer exposures at end-use are compared to the ATEL for HFC-134a, as shown in Section 9. For the occupational exposure analysis, described in Section 10, potential risks from chronic and acute worker exposure were evaluated by comparing exposure concentrations with available occupational exposure limits. Potential risks of chronic worker exposure were evaluated using workplace guidance levels (WGL), such as Workplace Environmental Exposure Levels (WEEL). Risks from potential acute occupational exposures at end-use were evaluated by comparing exposure concentrations to emergency guidance levels (EGL). In the absence of an established short-term exposure limit (STEL), acute exposure guideline level (AEGL), or emergency response planning guideline (ERPG) for HFC-134a, potential short-term, occupational exposures can be compared to an AEGL or EPA-derived STEL and the RCL. The STEL is a conservatively derived exposure limit that is intended to protect workers in an occupational setting in which they are exposed to these chemicals on a daily basis. The STEL does not represent a limit for a single exposure in a lifetime.

Table 5 lists the relevant exposure limits for HFC-134a, and is followed by Table 6, which provides an explanation of each exposure limit. EPA's approach for identifying or developing these values is discussed in Chapter 3 of the Background Document.

Table 5. Exposure Limits for HFC-134a

Proposed Substitute	WGL (Long-term Exposure) ppm	EGL (Short-term Exposure) ppm	RCL ppm	ATEL ppm
HFC-134a	1,000 (8-hour WEEL)	8,000 (10-min AEGL-1) 8,000 (30-min AEGL-1)	50,000	50,000

An explanation of each exposure limit and exposure-limit related terminology is described in Table 6.

Table 6. Explanation of Exposure Limit-Related Terminology[a]

Organization	Definition	
OSHA	Occupational Safety and Health Administration	
NIOSH	National Institute for Occupational Safety and Health	
ACGIH	American Conference of Governmental Industrial Hygienists	
AIHA	American Industrial Hygiene Association	
Exposure Limit	**Definition**	**Explanation**
Short-Term Exposure		
RCL	Refrigerant Concentration Limit	The RCL for a refrigerant is intended to reduce the risks of acute toxicity, asphyxiation, and flammability hazards in normally occupied, enclosed spaces. The RCL for each refrigerant is the lowest of the Acute-Toxicity Exposure Limit (ATEL), Oxygen Deprivation Limit (ODL), and Flammable Concentration Limit (FCL). Determination assumes full vaporization with no removal by ventilation, dissolution, reaction, or decomposition and complete mixing of refrigerant in the space to which it is released.
ATEL	Acute Toxicity Exposure Limit	The ATEL is the refrigerant concentration limit intended to reduce the risks of acute toxicity hazards in normally occupied, enclosed spaces according to ASHRAE Standard 34. The ATEL includes consideration of mortality, cardiac sensitization, anesthetic or central nervous system effects and other escape impairing effects and permanent injury. The ATEL is similar to the Immediately Dangerous to Life or Health (IDLH) concentrations set by NIOSH.
STEL	Short-Term Exposure Limit	A 15-minute time-weighted average (TWA) exposure that should not be exceeded during a workday, even if the 8-hour TWA is within the threshold limit value-time weighted average (TLV–TWA), set by ACGIH.

AEGL[b,c]	Acute Exposure Guideline Level 1	AEGL-1 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
Long-Term Exposure		
WEEL	Workplace Environmental Exposure Level	Developed by OARS for to protect healthy workers against acute and chronic health effects, this limit is based on repeated daily exposures over a working lifetime and averaged over an 8-hour workday.
TLV-TWA	Threshold Limit Value –Time-Weighted Average	The TWA concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect according to ACGIH.

[a] All information in this table taken from EPA (1994) except where otherwise noted.

[b] EPA (2012).

[c] Applicable to emergency exposure periods ranging from 10 minutes to 8 hours.

According to the SDS, exposure to HFC-134a may be hazardous if inhalation, skin contact, or eye contact with the proposed substitute occurs at sufficiently high levels. The most likely pathway of exposure is through inhalation. HFC-134a can cause symptoms of asphyxiation (e.g., headaches, ringing in ears, dizziness, drowsiness, nausea, vomiting, depression of all senses, and unconsciousness) when present in concentrations high enough to significantly lower oxygen concentrations below 19.5 percent by volume. Under some circumstances of over-exposure (i.e., oxygen levels fall below 6 percent by volume), death may occur.

If inhaled, HFC-134a can cause symptoms such as light-headedness, dizziness, confusion, incoordination, drowsiness, unconsciousness. Excessive inhalation of HFC-134a may also result in an irregular heartbeat or death due to cardiac effects. Furthermore, at high concentrations, HFC-134a inhalation can cause central nervous system depression, including dizziness, drowsiness, and headaches.

Exposures of the skin to HFC-134a (e.g., when released during a leak from the system) may cause frostbite or burns. In the case of dermal exposure, the SDS for HFC-134a recommends that person(s) immediately wash the affected area with water for at least 15 minutes while removing all contaminated clothing to avoid irritation; if frostbite occurs, bathe (do not rub) the affected area with lukewarm, not hot, water. If water is not available, cover the affected area with a clean, soft cloth. Exposures of HFC-134a to the eyes could cause eye irritation. In case of ocular exposure, the SDS for HFC-134a recommends that person(s) immediately flush the eyes, including under the eyelids, with copious amounts of water for 15 minutes.

EPA's review of the human health impacts of this proposed substitute is contained in the public docket for this decision. The potential health effects of HFC-134a can be minimized by following the exposure guidelines, ventilation, and PPE recommendations outlined in the SDS for HFC-134a and this risk screen.

7. FLAMMABILITY ASSESSMENT

HFC-134a is classified as an A1 refrigerant by ASHRAE Standard 34, and is considered to be nonflammable (Roland Engineering Services 2014; ASHRAE 2016b). Based on this classification, charging, servicing, and use of HFC-134a is not expected to present a flammability risk in retrofitted residential and light commercial AC and heat pumps.

8. ASPHYXIATION ASSESSMENT

The risk of asphyxiation for the reasonable worst-case scenario described in Section 5 was investigated for HFC-134a. In this section, risk of asphyxiation is assessed by modeling the oxygen concentration under the room size and maximum charge size specified in the worst-case scenarios.

This analysis does not consider ventilation or conditions that are likely to occur that would increase oxygen levels to which individuals would be exposed, such as open doors or windows, fans operating, conditioned airflow (either heated or cooled), or even openings at the bottom of doors that allow air to flow in and out. As specified in Section 5, this analysis assumes a vertical concentration gradient. If the proposed substitute passes the screening analysis with these restrictive assumptions in place, it can be reasonably assumed that no risks of asphyxiation will be present under real-world conditions. The results of the asphyxiation assessment are summarized in Table 7.

Table 7. Asphyxiation Assessment[a]

Equipment	Scenario	Charge Size (kg)	Effective Room Size (m^3)	Percent Oxygen Concentration[b]
Window AC	Reasonable Worst-Case 1	1	41 (1,450 ft^3)	21%
Ductless split System	Reasonable Worst-Case 2	5		20%
Ducted split System	Reasonable Worst-Case 3	10	136 (4,800 ft^3)	19%

Bold font indicates modeling results.
[a] Cells highlighted in green are the scenarios with acceptable exposure levels given various modeling assumption options.
[b] The typical concentration of oxygen in air is considered to be 21 percent (Mackenzie & Mackenzie 1995).

Based on the modeling assumptions, HFC-134a in window AC, ductless split systems, and ducted split systems does not present a significant risk of asphyxiation. In order for a risk of asphyxiation to occur, the normal concentration of oxygen in air (21 percent) must be reduced to 12 percent.[9] The charge sizes at which an asphyxiation concern would exist are significantly larger than the proposed charge sizes.

According to the worst-case modeling results, EPA does not believe that the use of HFC-134a in retrofitted residential and light commercial AC and heat pumps poses a significant risk of asphyxiation or impaired coordination to personnel, provided systems are installed in appropriate spaces according to guidelines from the manufacturer and the SDS for HFC-134a.

9. END-USE EXPOSURE ASSESSMENT

This section presents estimates of potential end-user exposures to HFC-134a in the event of a catastrophic release from the proposed substitute's use in window AC, ductless split systems, and ducted split systems under the reasonable worst-case scenario outlined in Section 5.

For the end-use exposure assessment scenario, 15-minute TWA exposures for the proposed substitute were calculated using the box model described in the Background Document, which was adapted to estimate concentrations on a minute-by-minute basis. Estimates for acute/short-term end-use exposures resulting from catastrophic leakage of refrigerant from window AC, ductless split systems, and ducted split systems were examined. As discussed in Section 5, the full charge of the unit is assumed to be

[9] Twelve percent oxygen in air is the NOAEL for hypoxia (ICF 1997).

emitted over the course of one minute. The analysis was undertaken to determine the 15-minute exposures for HFC-134a, which were then compared to the standard exposure limits presented in Table 5 to assess the risk to end-users. The estimated TWA values are fairly conservative as the analysis does not consider opened windows, fans operating, conditioned airflow (either heated or cooled) and other variables that would reduce the levels to which individuals would be exposed.

Under the reasonable worst-case scenario described in Section 5, the anticipated 15-minute TWA exposures of HFC-134a following catastrophic releases of window AC, ductless split systems, and ducted split systems were modeled with the lower air exchange rate of 0.11 ACH, which represents the air exchange rate in a tight construction home.

Table 8. End-Use Exposure Assessment[a]

Equipment	Scenario	Charge Size (kg)	Effective Room Size (m^3)	15-minute TWA End-Use Exposure[b] (ppm)
Window AC	Reasonable Worst-Case 1	1	41 (1,450 ft^3)	**13,100**
Ductless split System	Reasonable Worst-Case 2	5		**36,500**
Ducted split System	Reasonable Worst-Case 3	10	136 (4,800 ft^3)	**99,000**
Window AC	Threshold Analysis 1a: Charge Size	**3.8**	41 (1,450 ft^3)	50,000
Ductless split System	Threshold Analysis 2a: Charge Size	**6.9**		
Ducted split System	Threshold Analysis 3a: Charge Size	**5.1**	136 (4,800 ft^3)	
Window AC	Threshold Analysis 1b: Room Size	1	**11 (380 ft^3)**	
Ductless split System	Threshold Analysis 2b: Room Size	5	**30 (1,060 ft^3)**	
Ducted split System	Threshold Analysis 3b: Room Size	10	**270 (9,510 ft^3)**	

Bold font indicates modeling results.
[a] Cells highlighted in green are the scenarios with acceptable exposure levels given various modeling assumption options.
[b] ATEL of HFC-134a is equal to 50,000 ppm.

According to the results in Table 8, the estimated 15-minute TWA exposures for HFC-134a in retrofitted window AC and ductless split systems is not likely to exceed the ATEL (i.e., 50,000 ppm) in room volumes with 0.11 ACH (and therefore also not likely in rooms within a loose construction home with air exchange rates of 0.67 ACH). The modeling indicates that the estimated 15-minute TWA exposure for HFC-134a in ducted split systems could exceed the ATEL in room volumes with 0.11 ACH; however, the estimated exposures were derived using fairly conservative assumptions (e.g., minimum room volume, maximum charge size, low ventilation rate) that do not necessarily reflect the actual room attributes where HFC-134a residential and light commercial AC equipment will be retrofitted and used. Commonly used refrigerants in these applications would also yield similar results based on these conservative assumptions, therefore risks associated with the proposed substitute are not expected to be greater.

In order for toxicity to be of concern based on the results shown in Table 8, the charge sizes for window AC units or ductless splits systems would have to be at about 3.8 times and 1.4 times greater than the maximum modeled charge sizes, respectively. The minimum room sizes in which installed equipment could cause a toxicity concern vary in direct correlation with charge size. These results are significantly more conservative than the parameters modeled in the worst-case scenarios.

The threshold analyses shown in Table 8 also demonstrate the conditions at which an end-use exposure concern for the use of HFC-134a in ducted split system could exist, which are less conservative than the conditions assumed in the worst-case scenarios:

- Threshold Analysis 3a demonstrates that an end-use exposure concern could occur if the charge size of an HFC-134a ducted split system in a 136 m^3 (4,800 ft^3) room is approximately half the maximum charge size for ducted split systems as indicated by the submitter.

- For ducted split systems with a charge size of 10 kilograms, the end-use exposure could be a concern if the volume of the room was approximately twice the size of the modeled basement size (Threshold Analysis 3b).

Furthermore, it is unlikely that systems would be installed in smaller room sizes than modeled without additional ventilation, such as open doors or conditioned airflow, which is not considered in the analysis described above. Proper leak detection devices, engineering control requirements, and adherence to the SDS will further prevent exposures of HFC-134a during larger releases beyond the recommended exposure limits described in Table 5.

10. OCCUPATIONAL EXPOSURE ASSESSMENT

This section assesses potential exposure to workers during manufacture of HFC-134a, and retrofitting (i.e., charging), servicing, and disposal of HFC-134a retrofitted residential and light commercial AC and heat pumps using a box model approach. For a detailed description of the methodology used for this screening assessment, the reader is referred to the occupational exposure and hazard analysis described in Chapter 5 of the Background Document.

Estimates of refrigerant release per event for various release scenarios were obtained from the Vintaging Model.[10] For charging, servicing, and disposal activities, the release rate per event was multiplied by the number of events estimated to occur over a workday. The modeled exposure concentrations were compared to the STEL at charging and servicing in Table 9 and long-term exposure limits at disposal in Table 10.

10.1 Occupational Exposure at Manufacture of Proposed Substitute

[ ].

Release points and exposure during refrigerant blending operations would typically occur where temporary lines are connected or disconnected (i.e., filling of portable cylinders and portable bulk containers). To prevent significant exposure if such leaks occur, engineering controls should be used, including normal and local ventilation (e.g., chemical hoods) and vapor-in-air detection systems for standard manufacturing procedures so workers can avoid physical contact with the refrigerant and to achieve emission control. In general, use of PPE consistent with OSHA guidelines is recommended, such as respiratory protection (including a self-contained breathing apparatus (SCBA) in case of insufficient ventilation), tightly sealed goggles, and protective gloves (OSHA 1994).

In addition, as for other halogenated refrigerants, there is a risk of generation of toxic degradation products such as hydrogen fluoride, carbonyl halides, and carbon monoxide if HFC-134a is exposed to high temperatures or fire. Other reaction products such as carbon dioxide might also be present. Containers should be stored in cool, dry conditions in well-sealed receptacles and should not be allowed to contact open flames, glowing metal surfaces, or electrical heating elements. EPA believes that when proper handling and disposal guidelines are followed, in accordance with both good industrial hygiene and manufacturing practices, and the SDS for HFC-134a, there is no significant risk to workers during the manufacture of HFC-134a.

10.2 Occupational Exposure at Equipment Charging and Servicing

Residential and light commercial AC and heat pumps would be retrofitted with HFC-134a and serviced on-site at the end-use. The submitter indicates that HFC-134a is fully compatible with existing HCFC-22

[10] ICF maintains the Vintaging Model for EPA in order to simulate the aggregate impacts of the ODS phaseout on the use and emissions of various ODS and their substitutes over a period of several years across 65 different end-uses. The model tracks the use and emissions of various compounds for the annual vintages of new equipment that enter service in each end-use. The vintage of each type of equipment determines such factors as leak rate, charge size, number of units in operation, and the initial ODS substance that the equipment contained.

residential and light commercial AC and heat pumps; however, some equipment modifications may need to be made (Roland Engineering Services 2014). It is anticipated that service technicians would follow industry best practices to retrofit existing equipment.

Points of release for charging and servicing retrofitted residential and light commercial AC and heat pumps would be from connection/disconnection of temporary lines for charging and recovery equipment. There is also potential for exposure during the removal of the original refrigerant before the system is charged with HFC-134a; however, it is anticipated that existing systems would contain little or no refrigerant charge or would require replacement of a component (e.g., condensing unit) before being retrofitted with HFC-134a.

Charging and servicing activities for retrofitted residential and light commercial AC and heat pumps are not expected to result in significant worker exposure when certified technicians follow the procedures outlined in the HFC-134a SDS, the original refrigerant SDS, and equipment maintenance manual, undergo proper training, and wear appropriate PPE (e.g., gloves and safety glasses). Smaller room AC units (e.g., window AC, portable AC) are expected to be retrofitted and serviced rarely, since this type of equipment is hermetically sealed and is often replaced rather than serviced if the unit leaks. Nevertheless, the potential occupational exposure was analyzed for the maximum charge sizes for retrofitted residential and light commercial AC and heat pumps for those situations where servicing takes place were analyzed.

During charging and servicing of retrofitted residential and light commercial AC and heat pumps, the release per event was conservatively assumed to be 0.4 percent of the equipment charge. Furthermore, the number of events per workday was assumed to equal the maximum number of units anticipated to be serviced in one day (i.e., eight units divided by eight hours per workday).

To evaluate the risk of exposure at charging and servicing, the maximum 15-minute TWA exposure for HFC-134a was estimated for the servicing exposure scenario and compared to the RCL (see Table 9).

Table 9. Occupational Risk Assessment at Charging and Servicing[a]

Equipment	Charge Size (kg)	15-minute TWA (ppm)	15-min Short Term Exposure Limits (ppm)[b]	RCL (ppm)[b]
Window AC	1	1.0	8,000	50,000
Ductless split System	5	5.1		
Ducted split System	10	10		

Bold font indicates modeling results.
[a] Cells highlighted in green are the scenarios that are deemed to be acceptable given various modeling assumption options.
[b] See Table 5 for more information

The 15-minute STEL for HFC-134a is not exceeded in the charging and servicing exposure scenarios for retrofitted residential and light commercial AC and heat pumps with the maximum modeled charge sizes. Furthermore, the estimated exposures were derived using conservative assumptions, and do not take into account the use of additional engineering controls or PPE. Additionally, all of these exposure estimates are significantly lower than the RCL and ATEL for HFC-134a, which are limits intended to reduce the risks of asphyxiation, flammability, and acute toxicity hazards in normally occupied, enclosed spaces according to ASHRAE Standard 34. These types of systems are typically serviced by Section 608-certified personnel using proper industrial hygiene techniques and using proper engineering controls (e.g., local ventilation, refrigerant detectors, and alarm systems). Thus, EPA does not believe that charging or servicing of retrofitted residential and light commercial AC and heat pumps containing HFC-134a presents a significant concern to workers.

10.3 Occupational Exposure at Equipment Disposal

Disposal of HFC-134a retrofitted residential and light commercial AC and heat pumps is expected to occur with limited frequency (up to approximately ten disposal events per day at the end-use and with limited duration of exposure to the installed refrigerant). Typically, potential exposures to the refrigerant during recovery and disposal are expected to occur during activities related to decommissioning AC systems (e.g., attaching of hoses associated with draining or otherwise discharging of refrigerant from the refrigeration units into cylinders) and would be similar to those during servicing, because similar refrigerant charging and/or recovery equipment would be used (see Section 10.2 and Table 9 for information and modeling results related to exposure during servicing activities).

To model a worst-case scenario during disposal of retrofitted residential and light commercial AC and heat pumps, the release per event was conservatively assumed to be 100 percent of the equipment charge (representing a catastrophic release). It was assumed that 10 units are disposed during an 8-hour work day; however, it was assumed that of the 10 units, only the last unit per workday would experience the catastrophic release (i.e., 100 percent of the equipment charge). The remaining 9 units were assumed to release only an incidental amount of refrigerant (i.e., 1 percent per unit) from the connecting and disconnecting of lines, as it is likely that if a worker was exposed to the entire charge of a system during disposal activities, they would immediately stop working, clear the area until all refrigerant has been removed from the space (e.g., through ventilation), and adhere to the exposure procedures recommended in the SDS for the proposed substitute.

Table 10 displays the maximum estimated 8-hour TWA occupational exposure levels for HFC-134a at disposal.

Table 10. Occupational Risk Assessment at Disposal[a]

Equipment	Charge Size (kg)	8-Hour TWA Occupational Exposure (ppm)	8-Hour Long Term Exposure Limits (ppm)
Window AC	1.0	40	1,000[b]
Ductless split System	5.0	200	
Ducted split System	10	400	

Bold font indicates modeling results.
[a] Cells highlighted in green are the scenarios that are deemed to be acceptable given various modeling assumption options.
[b] 8-hour WEEL (See Table 5).

Under the disposal release scenarios, the modeling indicates that occupational exposure during disposal of retrofitted residential and light commercial AC and heat pumps at the maximum charge size is not a concern. The recommendations for proper engineering controls and PPE in the SDS for HFC-134a should be followed.

The estimated exposures were derived using conservative assumptions (e.g., no local exhaust ventilation), and represent a worst-case scenario with a low probability of occurrence. These types of systems are also typically disposed of by Section 608-certified personnel using proper industrial hygiene techniques to maximize recovery efficiency and limit releases, and there are already established standards of practice and training requirements that apply to fluorinated refrigerants to reduce exposures (and would therefore extend to HFC-134a systems).

Adequate ventilation should always be established during any use, handling, or storage of HFC-134a. Engineering controls should include vapor-in air detection systems and local exhaust ventilation during use of HFC-134a to prevent dispersion throughout the workplace. In addition, an eye wash and safety shower should be near the manufacturing facility and locations where HFC-134a is stored and ready for use. EPA believes that if proper handling and disposal guidelines are followed in accordance with good industrial hygiene and manufacturing practices, and the SDS for HFC-134a, there is no significant risk to workers during the manufacturing, charging, servicing, and disposal of HFC-134a in retrofitted residential and light commercial AC and heat pumps.

11. GENERAL POPULATION EXPOSURE

This section presents an assessment of potential risks to the general population posed by the use of HFC-134a in retrofitted residential and light commercial AC and heat pumps. The general population is defined in this risk screen as non-personnel who are subject to exposure of the proposed substitute near industrial facilities, including manufacturing or equipment production factories production factories, equipment operating sites, or recycling centers, rather than personnel at end-use.

HFC-134a is not expected to cause a significant concern to human health in the general population when used as a refrigerant in retrofitted residential and light commercial AC and heat pumps. The proposed substitute is proposed for use in closed systems, and thus, significant releases are not anticipated. At room temperature, HFC-134a is a gas, and therefore, releases to ground or surface water are not anticipated, as HFC-134a is expected to dissipate into the atmosphere upon release to outside air (i.e., because natural ventilation rates would be higher and there is no enclosed space to maintain a high concentration of HFC-134a). Should air releases during manufacturing operations occur, engineering controls should be used (e.g., carbon absorption scrubbers) to collect HFC-134a and prevent its release into the atmosphere. EPA believes that by using proper engineering controls and by following disposal and containment recommendations outlined in the proposed substitute's SDS and this risk screen, exposure to HFC-134a in retrofitted residential and light commercial AC and heat pumps is not expected to pose a significant toxicity risk to the general population.

12. REFERENCES

Air Conditioning Contractors of America (ACCA). 2006. Manual J, Residential Load Calculation Eighth Edition.

AHRI. 2014. Standard 700: Specifications for Refrigerants. Air-conditioning, Heating and Refrigeration Institute.

ANSI/UL. 2012. UL 484: Standard for Room Air Conditioners. 8th Edition.

ANSI/ASHRAE. 2016a. Standard 15-2016: Safety Standard for Refrigeration Systems. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ANSI/ASHRAE. 2016b. Standard 34-2016: Designation and Safety Classification of Refrigerants. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ANSI/ASHRAE. 2016c. Standard 62.1-2016: Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland. 2007. Changes in Atmospheric Constituents and in Radiative Forcing. *In: Climate Change 2007:The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

ICF International. 1997. Physiological Effects of Alternative Fire Protection Agents - Hypoxic Atmospheres Conference. Stephanie Skaggs prepared the proceedings of the conference held May 22, 1997 in New London, CT.

Kataoka, O., M. Yoshizawa, & T. Hirakawa. 2000. Allowable Charge Limit of Flammable Refrigerants and Ventilation Requirements. Daikin Industries. International Refrigeration and Air-conditioning Conference. Paper 506. Available online at: http://docs.lib.purdue.edu/iracc/506.

Roland Engineering Servies, LLC. 2014. Summit Plus. Significant New Alternatives Policy Program Submission to the United States Environmental Protection Agency. February 2014.

United Nations Environment Programme (UNEP). 2015a. Fact Sheet 7: Small Self-Contained Air-Conditioning. UNEP Ozone Secretariat Workshop on HFC management: technical issues. Bangkok, 20 and 21 April 2015. Available online at: http://conf.montreal-protocol.org/meeting/workshops/hfc_management-02/presession/English/FS%207%20Small%20self%20contained%20air-conditioning%20final.pdf

United Nations Environment Programme (UNEP). 2015b. Fact Sheet 9: Large Air-Conditioning (air-to-air). UNEP Ozone Secretariat Workshop on HFC management: technical issues. Bangkok, 20 and 21 April 2015. Available online at: http://ozone.unep.org/sites/ozone/files/Meeting_Documents/HFCs/FS_9_Large_air_to_air_air-conditioning_Oct_2015.pdf

U.S. Department of Energy (DOE). 2016. 2017 U.S. DOE Race to Zero Student Design Competition Guide. Available at: http://energy.gov/sites/prod/files/2016/06/f33/2017-RacetoZero-Guide-June16.pdf.

U.S. EPA. 1994. Significant New Alternatives Policy Technical Background Document: Risk Screen on the Use of Substitutes for Class I Ozone-depleting Substances: Refrigeration and Air Conditioning. Stratospheric Protection Division. March, 1994.

U.S. EPA. 2012. Acute Exposure Guidelines (AEGLs) Definitions. Available online at: http://www.epa.gov/oppt/aegl/pubs/define.htm.

WMO (World Meteorological Organization). 2011. Scientific Assessment of Ozone Depletion: 2010, Global Ozone Research and Monitoring Project—Report No. 52, 516 pp., Geneva, Switzerland, 2011.